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The R.T.H. Varotal IX:

A 10 to 1 zoom lens for use with the Philips three-tube Plumbicon colour camera

TECHNOLOGICAL REPORT No. T-174

UDC 681.42.08:621.397.132 1966/41

THE BRITISH BROADCASTING CORPORATION
ENGINEERING DIVISION

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for Head of Research Department

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SUMMARY

Measurements of modulation transfer function, vignetting and transmission are reported upon for the lens No. 635930. In addition the modulation transfer function (m.t.f.) is given for three focal length settings with a two times focal length range extender fitted to the rear of the lens. A second lens No. 684811, assembled under conditions of maximum cleanliness is reported upon with regard to transmission, veiling glare and modulation transfer function. A subjective assessment of the image quality obtained throughout the focal length range of the lens is given for both the full aperture and one stop down.

1. INTRODUCTION

The Varotal IX, 10-to-1, zoom lens is designed for use with the Philips Plumbicon colour camera, the lens having the required rear image distance and optical corrections for the colour analysis block.

A brief summary of the lens specification is given below:-

Focal length range:	20 to 200 mm
Maximum aperture:	f/2·0
Image format:	17·12 mm × 12·84 mm
Minimum object distance for zoom operation:	1·8 metre

The test procedure followed that employed with previous 10-to-1 zoom lenses.[1,2,3]

The m.t.f. measurements reported are for tungsten white illumination. It might be argued that a narrow-band light source approximating to the green channel of the Plumbicon colour camera would be more appropriate to the expected working conditions of the lens, any lateral chromatic aberrations being treated as a change in image magnification which may be corrected by the available camera controls. A visual examination of the image quality throughout the focal length range of the lens showed no fixed pattern of lateral chromatic aberration, that is no one setting of scan amplitudes will correct the lateral chromatic aberrations throughout the focal length range. The use of a tungsten white light source, whilst not giving the optimum performance at any one focal length setting, will give a good approximation to the overall optical performance throughout the focal length range.

2. RESULTS

2.1. Modulation Transfer Function

2.1.1. Lens No. 635930

The m.t.f. of the lens for the full aperture of f/2·0 and one stop down at f/2·8 were determined for the focal length settings of 20, 30, 40, 60, 90, 140 and 200 mm. The test object was effectively located at infinity and the focus condition for each focal length setting was that giving the maximum response on axis, at the spatial frequency of 17 c/mm.* The zoom focus tracking error was determined and found to be not greater than 10 μm, this figure being of the same order as the experimental accuracy. The results obtained with the aperture setting of f/2·0 are shown in Figs. 1 to 7, the results with the aperture of f/2·8 are shown in Figs. 8 to 14. The variation in response at the spatial frequency of 16·7 c/mm over the focal length range of the lens for the four image field positions tested is shown in Fig. 15 for f/2·0 and Fig. 16 for f/2·8 operation. A marked improvement

* For the British 625-line television standard, 16·7 c/mm corresponds to 5·5 MHz.

results from operating the lens at a reduced aperture, the improvement being generally between 10 and 15% in modulation transfer factor.

2.1.2. Lens No. 684811

Measurements of m.t.f. were restricted to comparison measurements at the full aperture for the extremities of the focal length range only. The result for 20 mm focal length at f/2·0 is shown in Fig. 17, and for 200 mm focal length in Fig. 18. Comparisons of Fig. 1 with Fig. 17 and Fig. 7 with Fig. 18 give some indication of the likely spread in performance of production lenses. At 20 mm focal length the performances are very similar, at 200 mm focal length the lens No. 635930 is slightly superior, especially for off-axis images.

2.1.3. Lens No. 635930 with Focal-Length Range Extender

The twice-focal-length range extender was fitted in accordance with the manufacturer's instructions to the rear of the main zoom lens. The range extender alters the lens specification to give a focal length range of 40 to 400 mm with a maximum aperture of f/4; when correctly fitted, no alteration of the rear image plane position relative to the position with the zoom lens alone is required.

Three focal lengths only were used for these tests, namely 20, 60 and 200 mm focal length settings on the main zoom lens. The results are shown in Figs. 19, 20 and 21. A steep fall in response at low spatial frequencies is apparent, the response at the cut-off frequency of 16·7 c/mm being about 25 to 30%. The steep fall in response is explained by the action of the range extender, which enlarges the image formed by the main zoom lens, the used format area remaining constant. To obtain a 17 c/mm pattern relative to the used format area of the enlarged image, the main zoom lens must transmit a pattern of twice that frequency, that is 34 c/mm. Reference to the full aperture performance of the zoom lens for 20, 60 and 200 mm focal length settings indicates an extrapolated response at the spatial frequency of 34 c/mm of about 20 to 30%. The performance of the zoom lens with the focal length range extender is poor at full aperture (f/4), and use of electronic frequency correction would probably result in an unacceptable increase of noise with the large correction required.

The subjective assessment of the image sharpness is dealt with in Section 4.

2.2. Transmission and Veiling Glare Index

Instrumental difficulties limited the measurements on the lens No. 635930. Full measurements were made on the cleanly-assembled lens No. 684811, the transmission results are given below:-

Lighting	Tungsten 2850°K	Blue 450 nm	Green 550 nm	Red 600 nm
Transmission %	76	62	79	79

Narrow-band dielectric filters were used to obtain transmission measurements at wavelengths near to the peak responses of the camera colour analysis characteristics. Transmission measurements on lens No. 635930 gave results between 5 and 8% lower than lens No. 684811.

The veiling glare index[4] of the lens No. 684811 was determined for focal length settings throughout the focal length range. The results are shown in Fig. 22, the lens being operated at the full aperture of f/2·0. The BBC specification for zoom lenses, TV/139,* sets a limit to the veiling glare index of 1·5%; the zoom lens Varotal IX does not exceed this limit, the maximum value for veiling glare being 1·3%.

2.3. Vignetting Characteristics

Measurements of the variation of illumination over the image field were made for the seven focal length settings of 20, 30, 40, 60, 90, 140 and 200 mm. The vignetting characteristics obtained with the full aperture of f/2·0 are shown in Fig. 23, the characteristics obtained with the lens operated one stop down at f/2·8 are shown in Fig. 24. For both apertures there is a sharp cut-off of image illumination near the limit of the image field diagonal. A sharp drop in illumination besides having a serious subjective effect,** severely prohibits camera tube overscanning and also requires precise alignment of the camera tubes with the lens.

The relative peripheral illuminations over the focal length range are compared in Fig. 25 for the two test apertures.

3. GEOMETRICAL DISTORTION

The geometrical distortion of the lens was not measured. The lens type Varotal IX is similar in design to the lens type Varotal V, the main difference being in the group of elements at the rear of the lens to give the required format size. In view of the similarity of design, the geometrical dis-

* Not yet published.

** Although the confirmatory experimental work has not yet been carried out, it is believed that a sharp drop in illumination inside the image field leads to a more serious subjective impairment than a continuous slope to the same value of peripheral illumination.

tortion of the lens type Varotal IX is expected to be similar to that of the lens type Varotal V.[1]

4. SUBJECTIVE ASSESSMENT

The modulation transfer function may be related to the subjective assessment of the image sharpness,[5] the integration of the m.t.f. up to the cut-off frequency giving the sharpness factor of the image field position under consideration. The subjective assessment of the image sharpness over the entire image field may be obtained by taking into account the varying visual importance over the image field.[6]

The variation in sharpness factor is shown in Fig. 26 for the four image field positions tested and for operation at f/2·0 and in Fig. 27 for operation at f/2·8.

The overall subjective assessment in limens of the image sharpness integrated over the image field is shown in Fig. 28. The subjective assessment of sharpness stated in limens may be related to the six-point Quality Scale,*[7] the scale 'score' varying between 1½ and 2 for operation at f/2·8, and between 2 and 2½ for f/2·0 operation.

The sharpness impairment in limens is given below for the lens No. 635930 with the two times focal-length range extender.

Focal length setting on main zoom lens	20 mm	60 mm	200 mm
Subjective impairment of sharpness in limens	3·6	3·5	4·6

The subjective impairments obtained with the focal length range extender would score ratings of 'rather poor' to 'poor' on the six-point scale.

The subjective assessment in limens of the vignetting characteristics may also be obtained,[6] the total impairment of the image quality being the sum of the sharpness and vignetting impairments. The vignetting impairment and the total impairment for both f/2·0 and f/2·8 are shown in Fig. 29.

5. CONCLUSION

Lack of information precludes comparison with other lenses designed for use with the Philips Plumbicon colour camera.

The lens type Varotal IX will give good image sharpness quality over the focal length range of the lens, the negligible zoom focus tracking error ensuring easy operation to obtain this standard.

The veiling glare performance of the lens is excellent for a zoom lens. The axial transmission is also excellent, although unless all lenses are assembled to the same standard as lens No. 684811 a reduction of about 5% in transmission may well be expected.

The vignetting at full aperture is poor, the sharp drop in image illumination inside the image field prohibiting tube overscanning and requiring precise alignment of the camera tubes with the lens. This criticism applies mainly for use with the enlarged 21·4 mm field diagonal; use of the lens with camera tubes restricted to 20 mm diagonal would obviate most of this particular criticism.

The lens has a minimum object working distance of 6 ft (1·8 m) and this will tend to limit its use to outside broadcast applications.

6. REFERENCES

1. Varotal V. A 10 to 1 zoom lens for the image orthicon format (No. 617566). BBC Research Department Report No. T-112, Serial No. 1963/36.

2. Performance of 10 to 1 zoom lens for image orthicon format: (type 10 × 35B No. 1095308). BBC Research Department Report No. T-144, Serial No. 1965/6.

3. Performance of the lens type 10 × 15D (No. 1121958) a 10 to 1 zoom lens for vidicon format. BBC Research Department Report No. T-149, Serial No. 1965/30.

4. Secondary flare in lenses. *BBC Engng Monogr.*, 1961, No. 36, Some aspects of optical lens performance. Pat. 1, pp. 5 - 14.

5. SPROSON, W.N. 1958. The subjective sharpness of television pictures. *Electron. Radio Engr.*, 1958, **35**, 4, pp. 124 - 132.

6. New equipment and methods for the evaluation of the performance of lenses for television. *BBC Engng Monogr.*, 1957, No. 15.

7. The K-rating of lenses. BBC Research Department Report No. T-167, Serial No. 1966/18.

* The six-point Quality Scale 1 is as follows:
1 - excellent, 2 - good, 3 - fairly good, 4 - rather poor, 5 - poor, 6 - very poor.

SMW

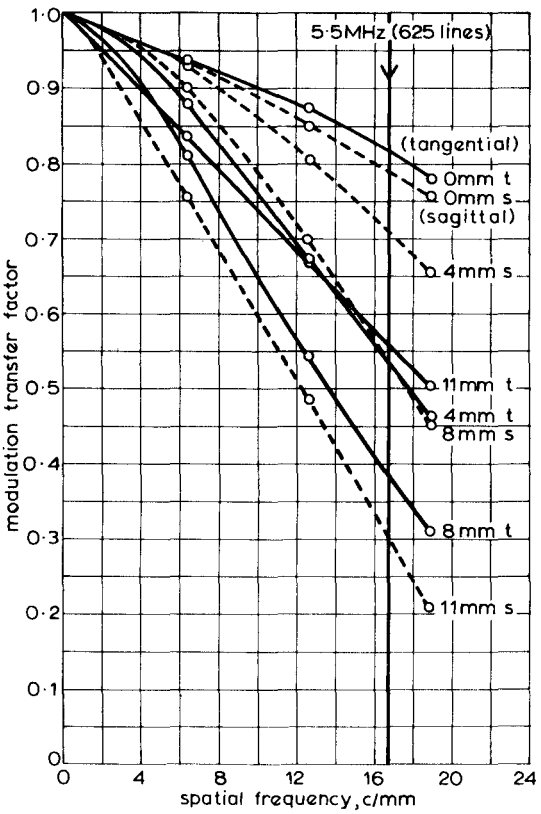

Fig. 1 - Modulation transfer function

20 mm focal length at f/2 Test object at infinity
Lens No. 635930

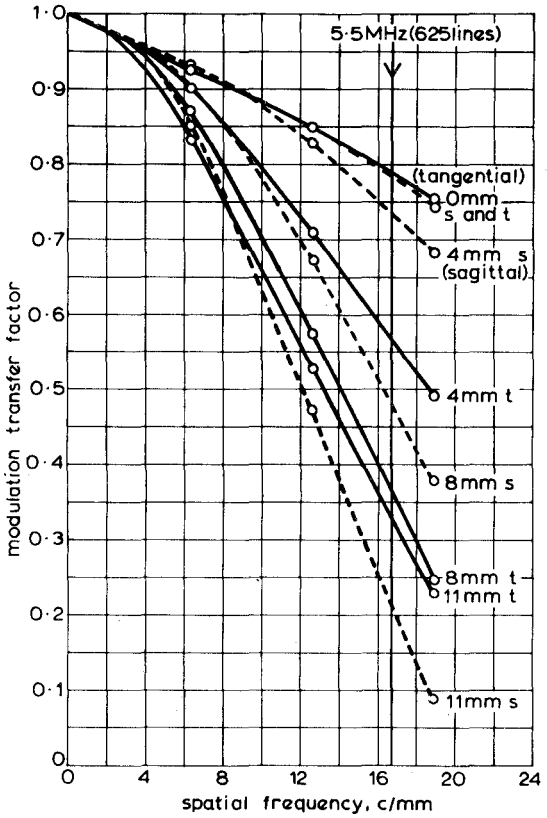

Fig. 2 - Modulation transfer function

30 mm focal length at f/2·0 Test object at infinity
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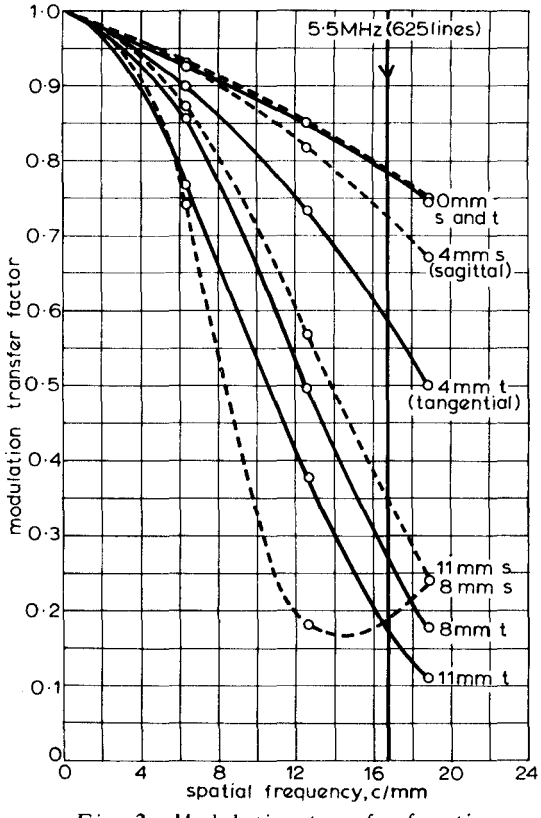

Fig. 3 - Modulation transfer function

40 mm focal length at f/2·0 Test object at infinity
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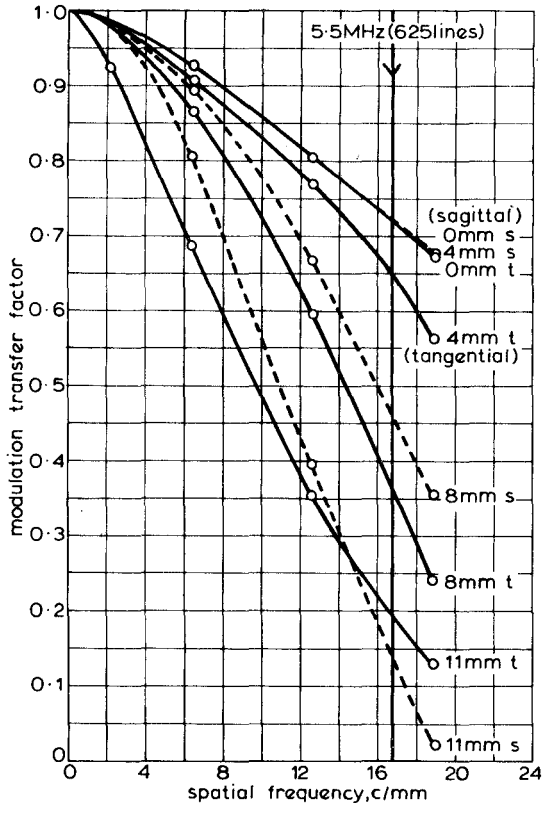

Fig. 4 - Modulation transfer function

60 mm focal length at f/2 Test object at infinity
Lens No. 635930

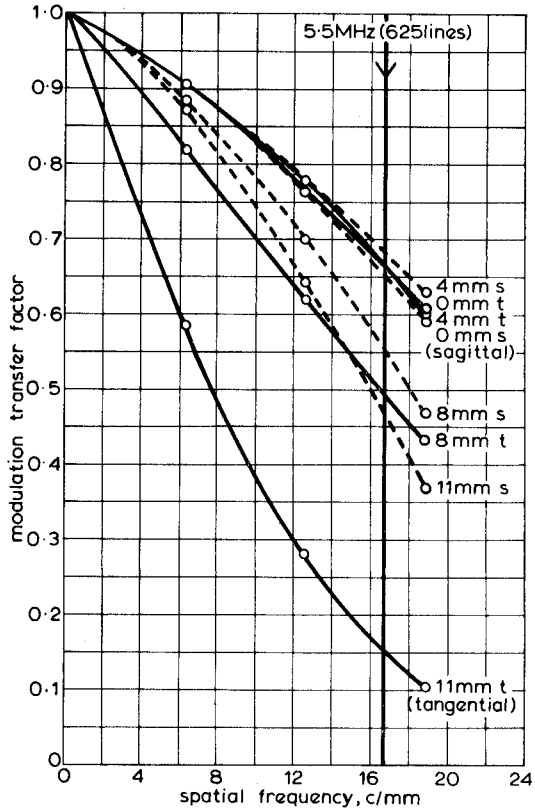

Fig. 5 - Modulation transfer function

90 mm focal length at f/2 Test object at infinity
Lens No. 635930

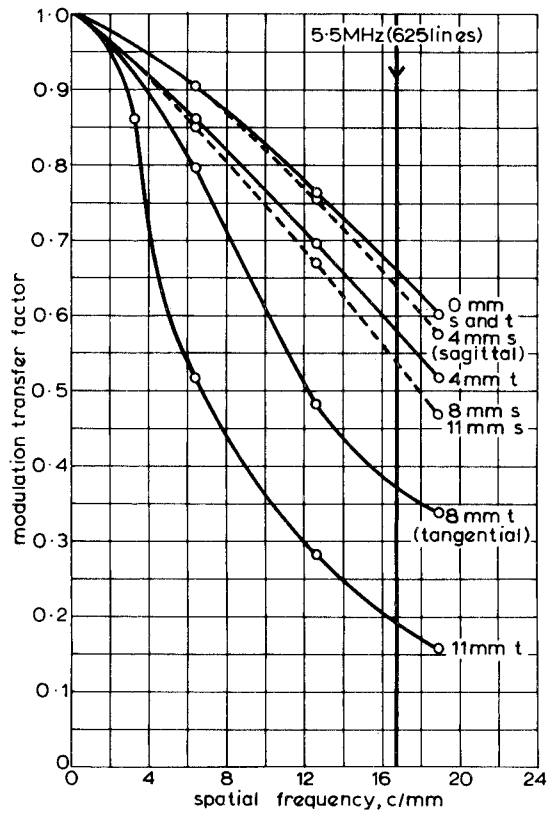

Fig. 6 - Modulation transfer function

140 mm focal length at f/2·0 Test object at infinity
Lens No. 635930

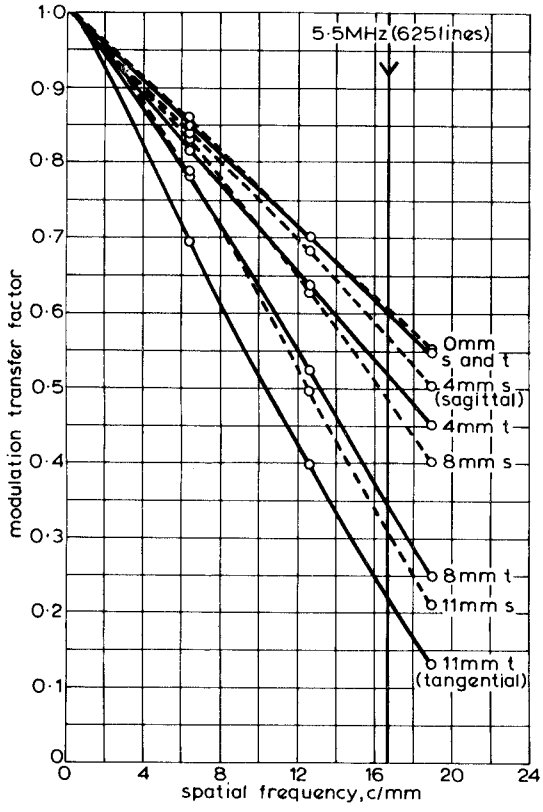

Fig. 7 - Modulation transfer function

200 mm focal length at f/2·0 Test object at infinity
Lens No. 635930

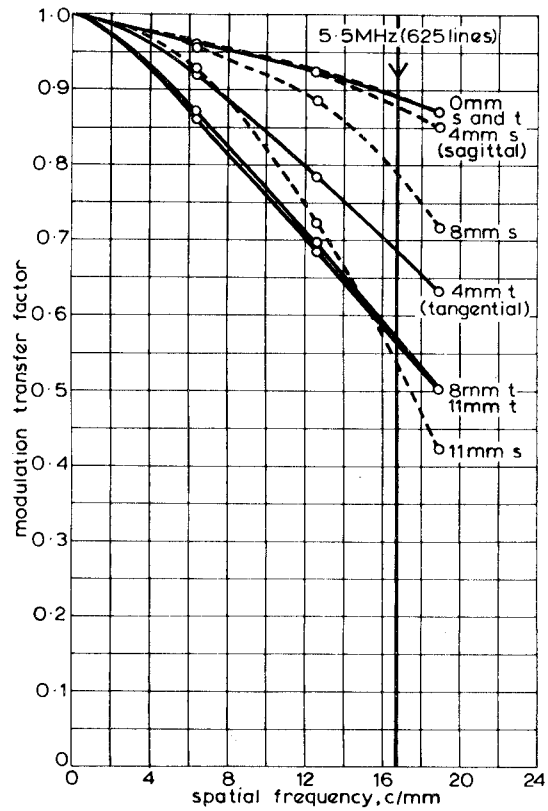

Fig. 8 - Modulation transfer function

20 mm focal length at f/2·8 Test object at infinity
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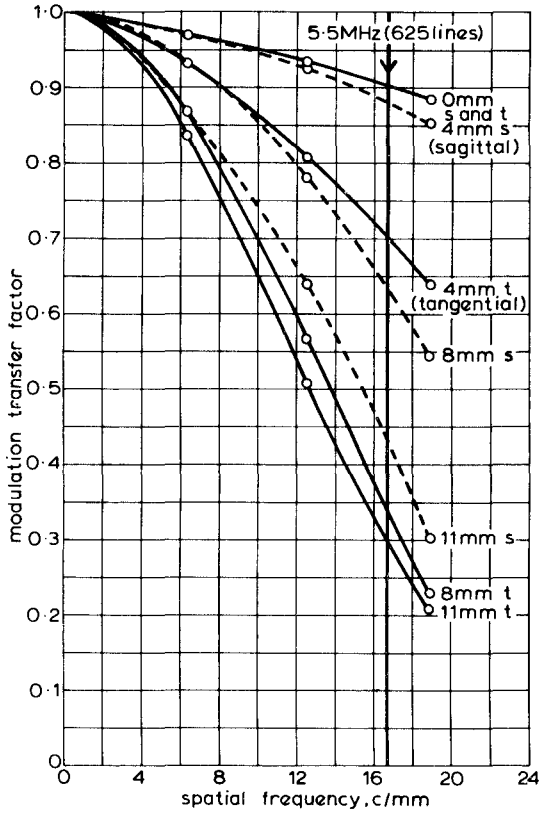

Fig. 9 - Modulation transfer function

30 mm focal length at f/2·8 Test object at infinity
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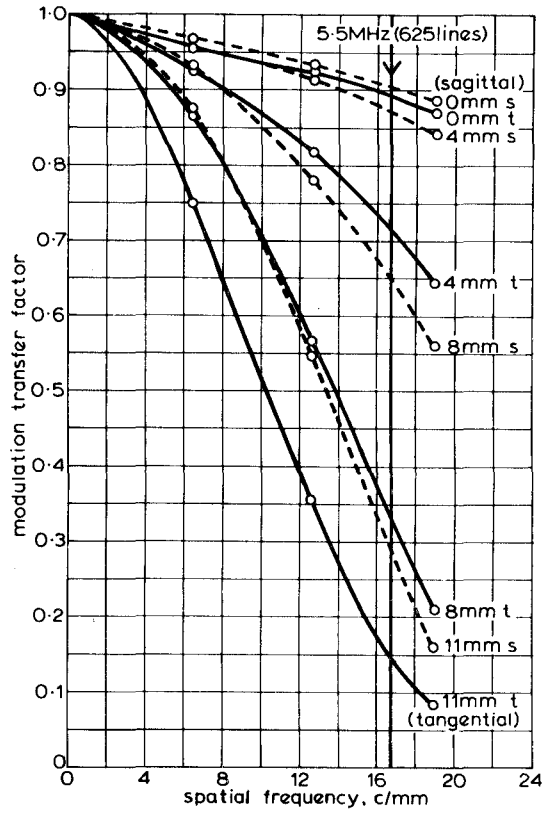

Fig. 10 - Modulation transfer function

40 mm focal length at f/2·8 Test object at infinity
Lens No. 635930

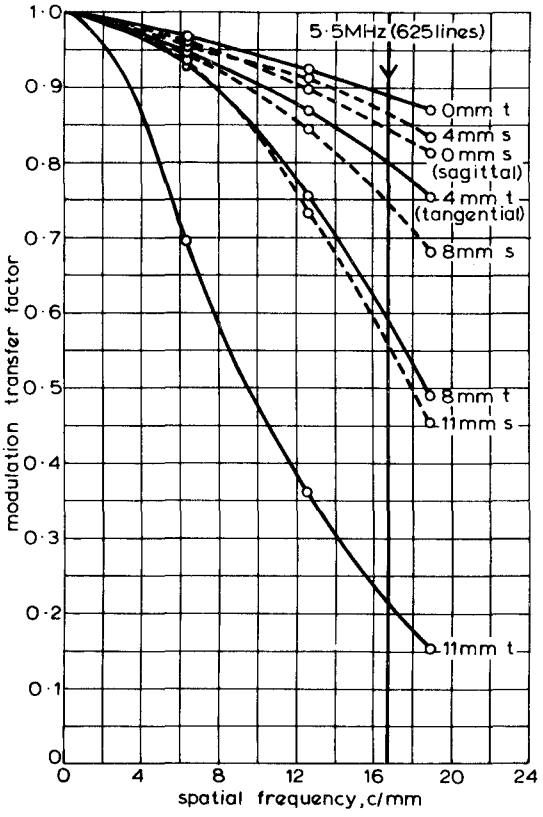

Fig. 11 - Modulation transfer function

60 mm focal length at f/2·8 Test object at infinity
Lens No. 635930

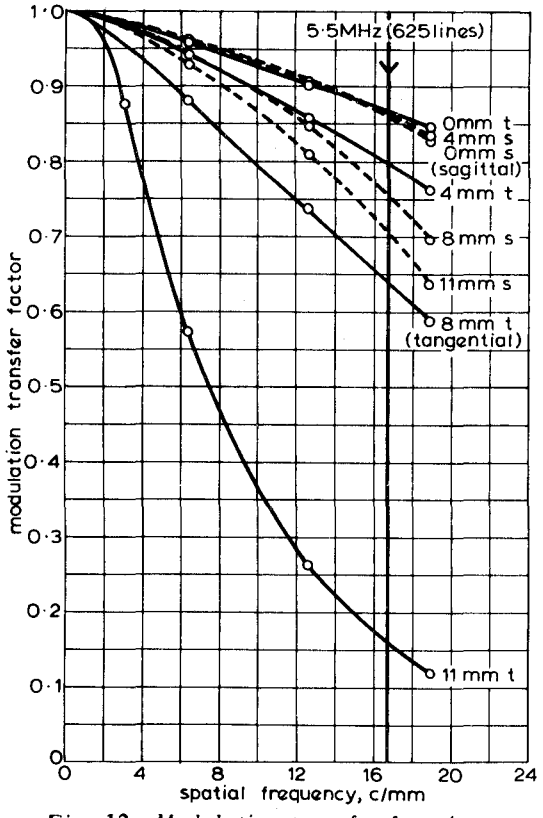

Fig. 12 - Modulation transfer function

90 mm focal length at f/2·8 Test object at infinity
Lens No. 635930

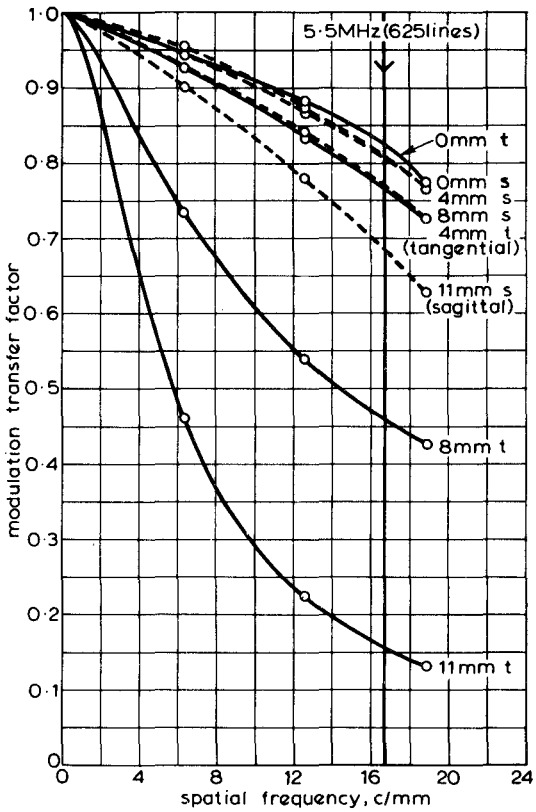

Fig. 13 - Modulation transfer function

140 mm focal length at f/2·8 Test object at infinity
Lens No. 635930

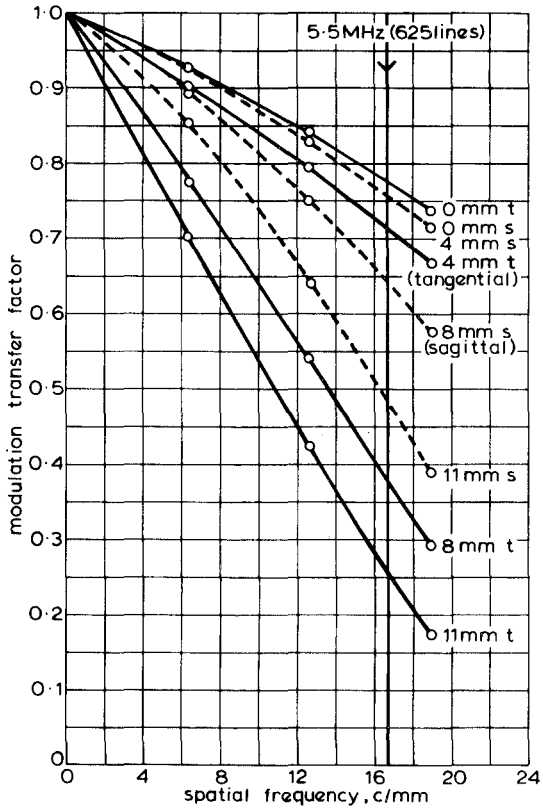

Fig. 14 - Modulation transfer function

200 mm focal length at f/2·8 Test object at infinity
Lens No. 635930

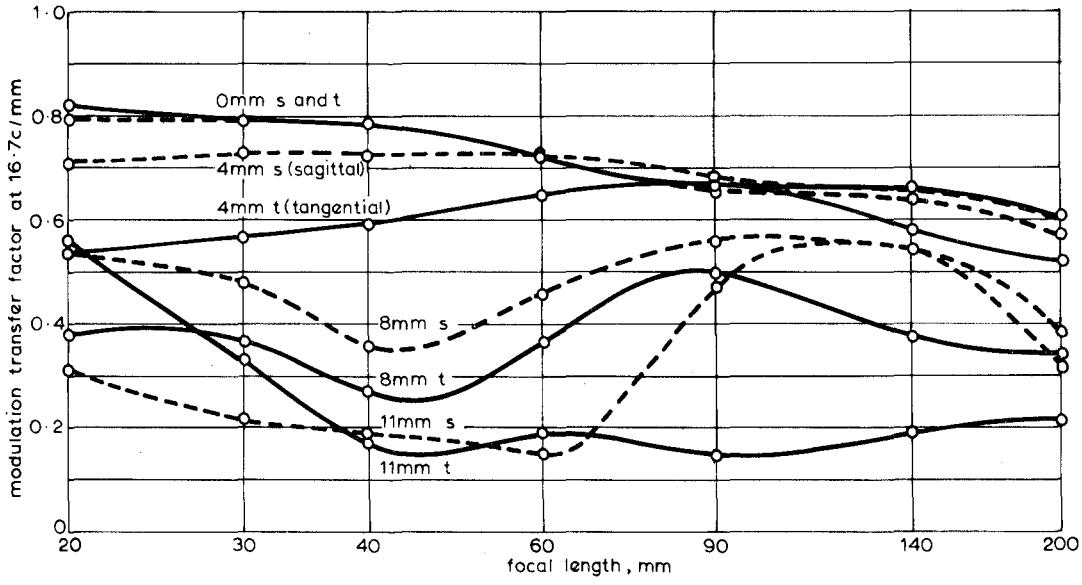

Fig. 15 - Modulation transfer factor at 16·7 c/mm

Lens aperture f/2·0 Test object at infinity

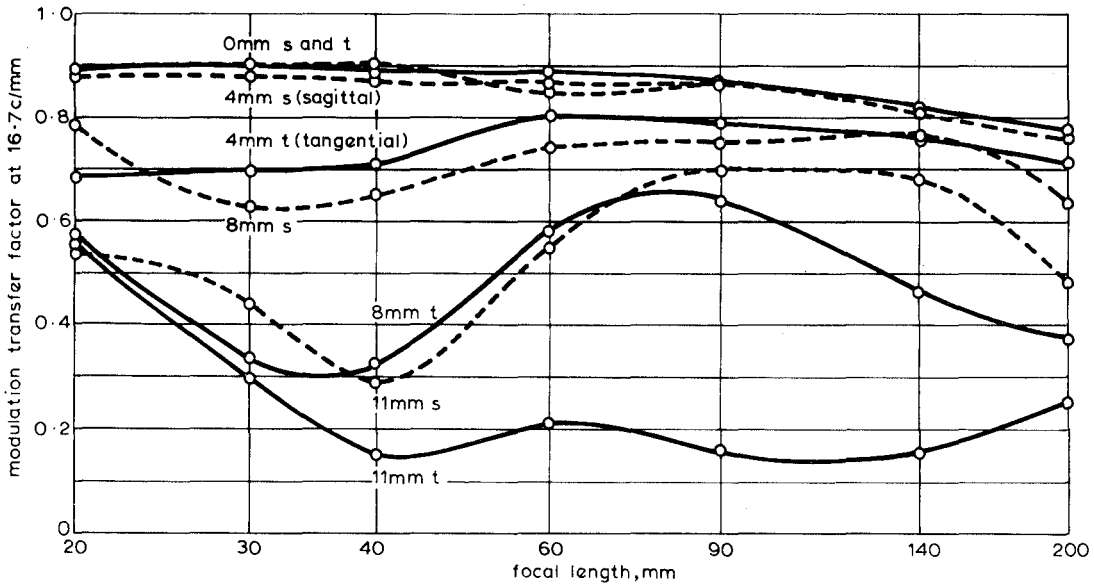

Fig. 16 - Modulation transfer factor at 16·7 c/mm

Lens aperture f/2·8 Test object at infinity

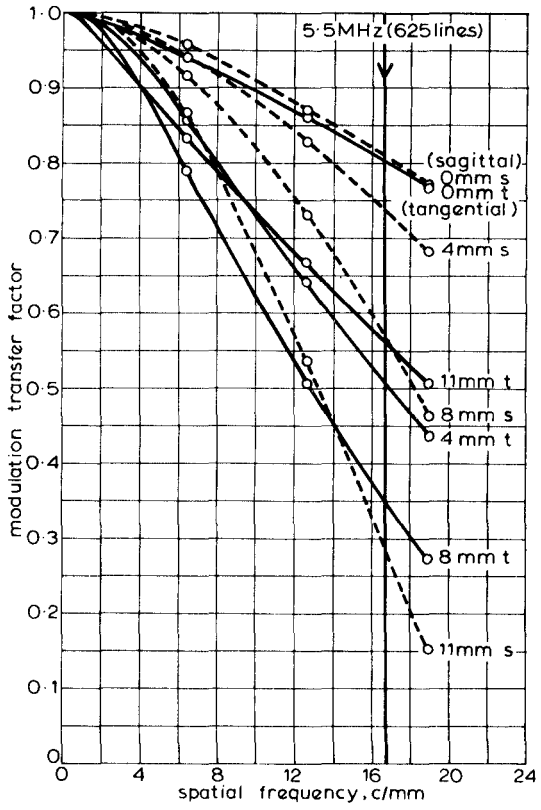

Fig. 17 - Modulation transfer function

20 mm focal length at f/2 Test object at infinity
Lens No. 684811

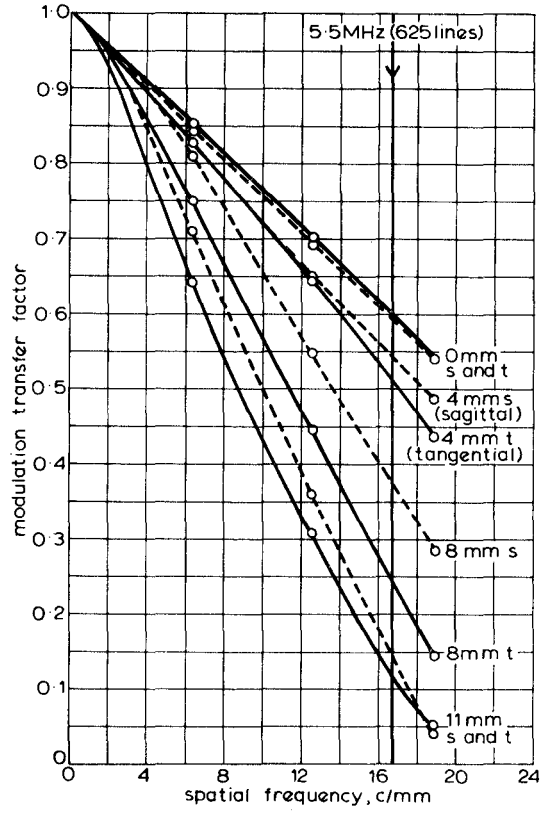

Fig. 18 - Modulation transfer function

200 mm focal length at f/2 Test object at infinity
Lens No. 684811

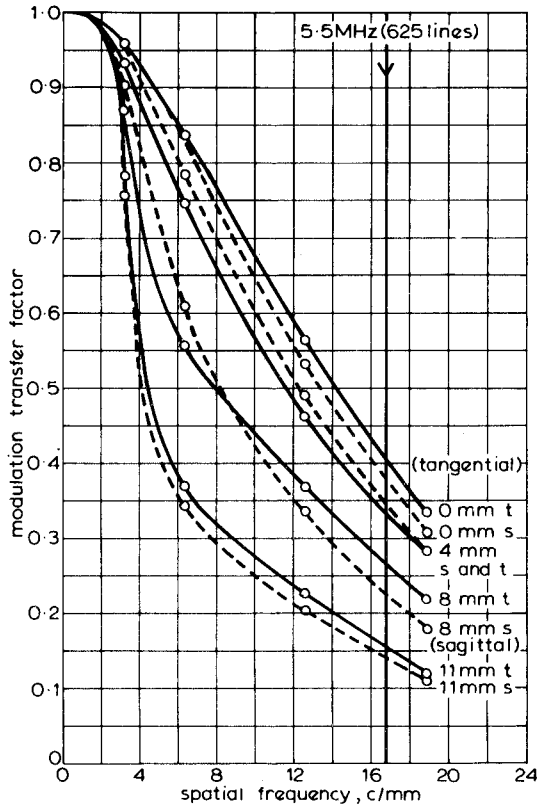

Fig. 19 - Modulation transfer function

20 mm at f/2 with 2× range extender ≡ 40 mm at f/4
Object at infinity Lens No. 635930

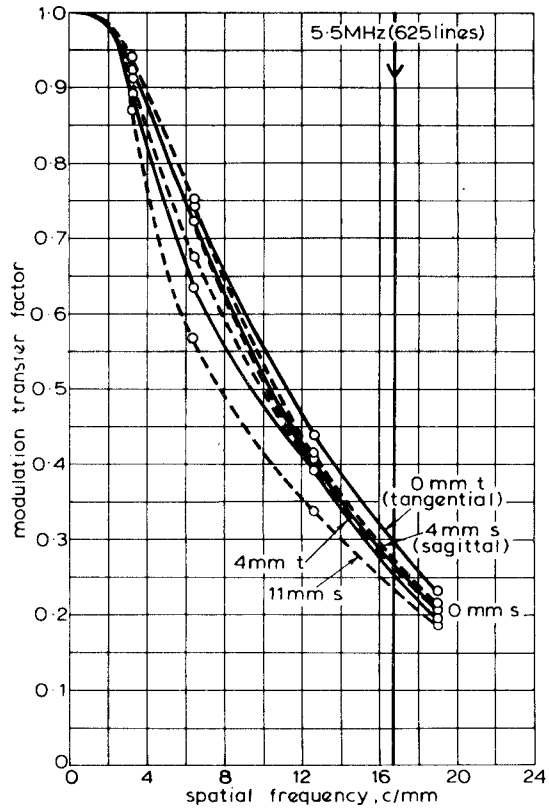

Fig. 20 - Modulation transfer function

60 mm focal length at f/2 0
with 2× range extender ≡ 120 mm at f/4·0
Object at infinity Lens No. 635930

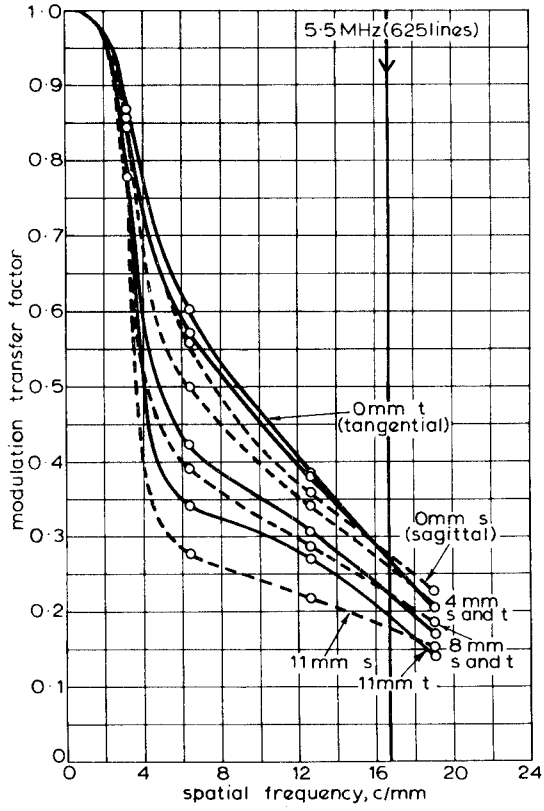

Fig. 21 - Modulation transfer function

200 mm at f/2 with 2× range extender ≡ 400 mm at f/4
Test object at infinity Lens No. 635930

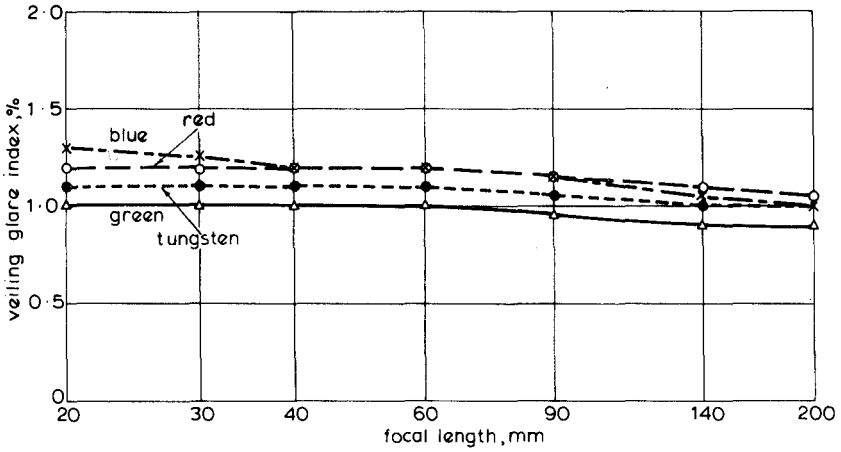

Fig. 22 - Veiling glare index

Lens No. 684811 at f/2·0

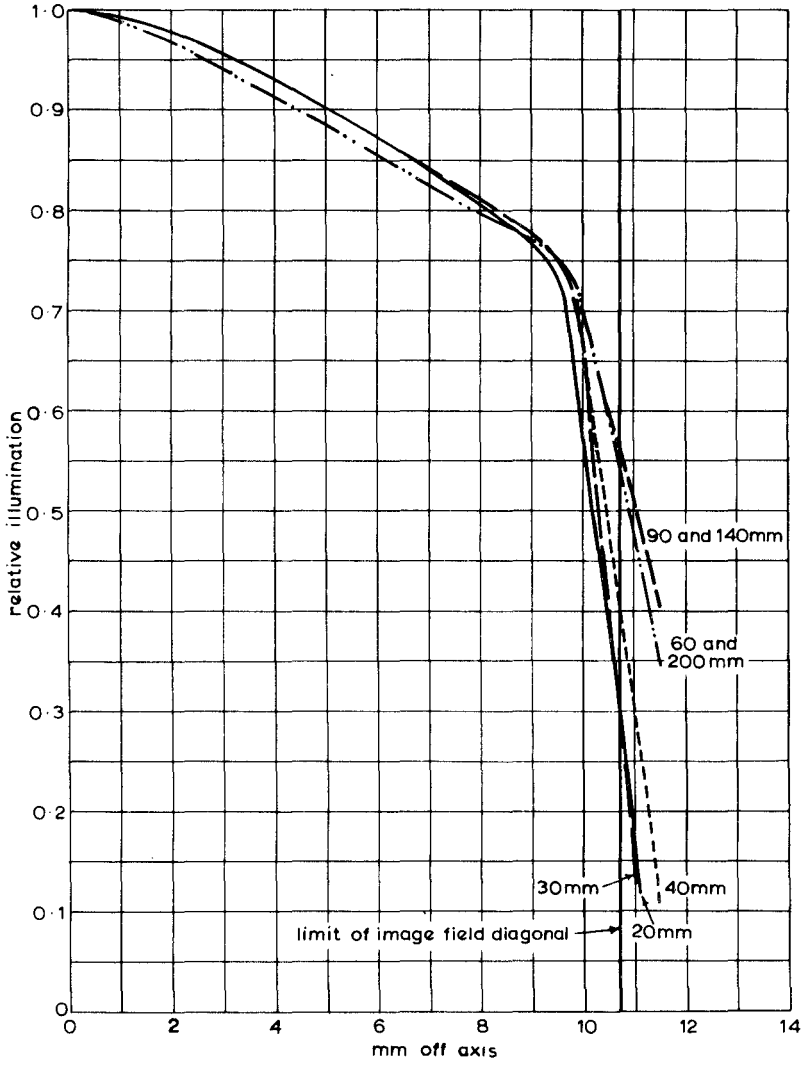

Fig. 23 - Vignetting characteristics

Aperture f/2·0 Lens No. 635930

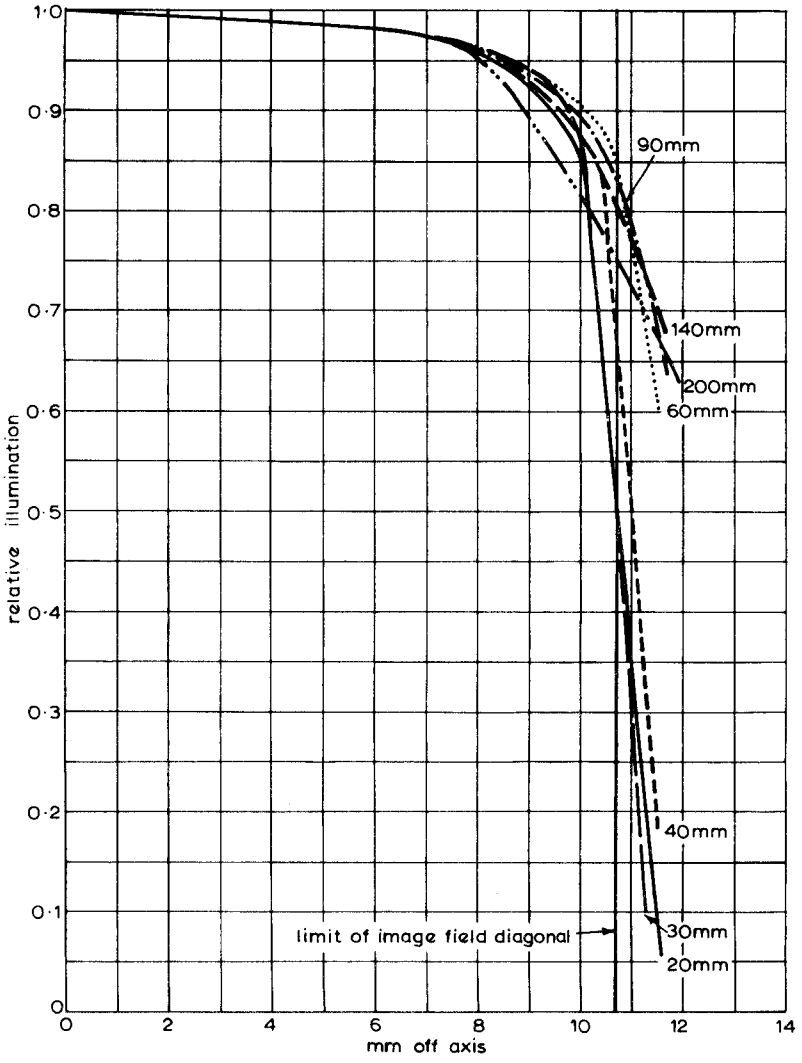

Fig. 24 - Vignetting characteristics

Aperture f/2:8 Lens No. 635930

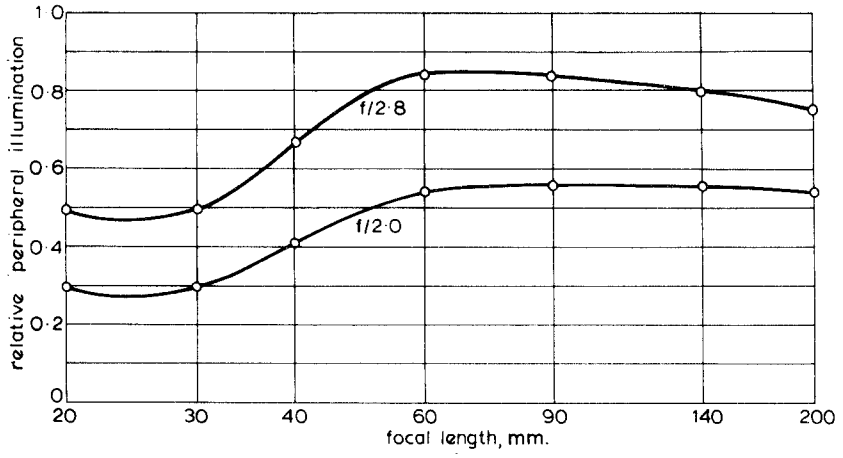

Fig. 25 - Relative illumination at image field periphery

Lens No. 635930

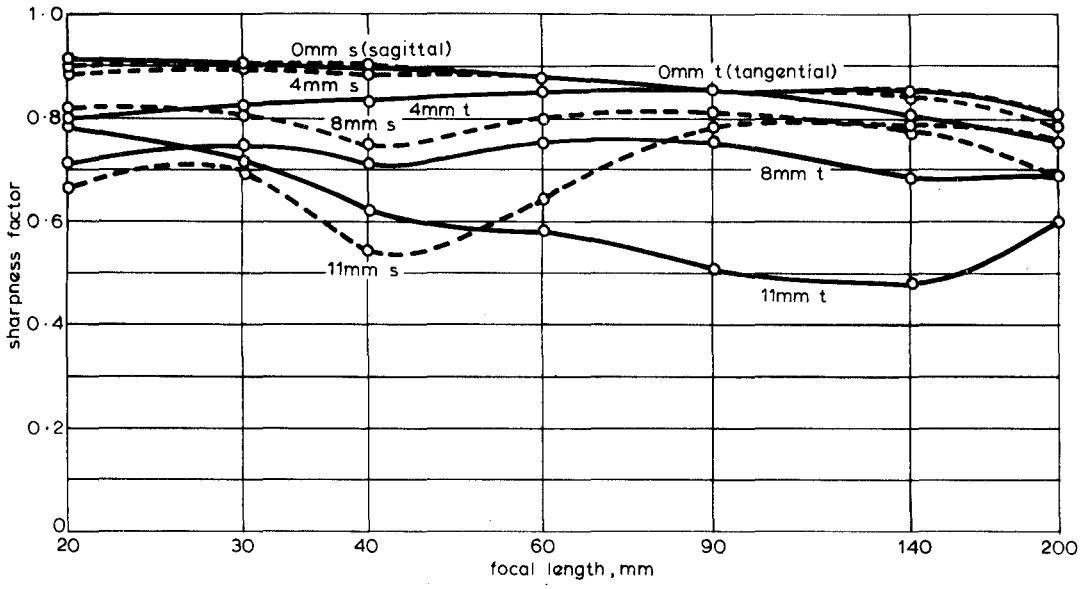

Fig. 26 - Sharpness factor at f/2·0

Lens No. 635930

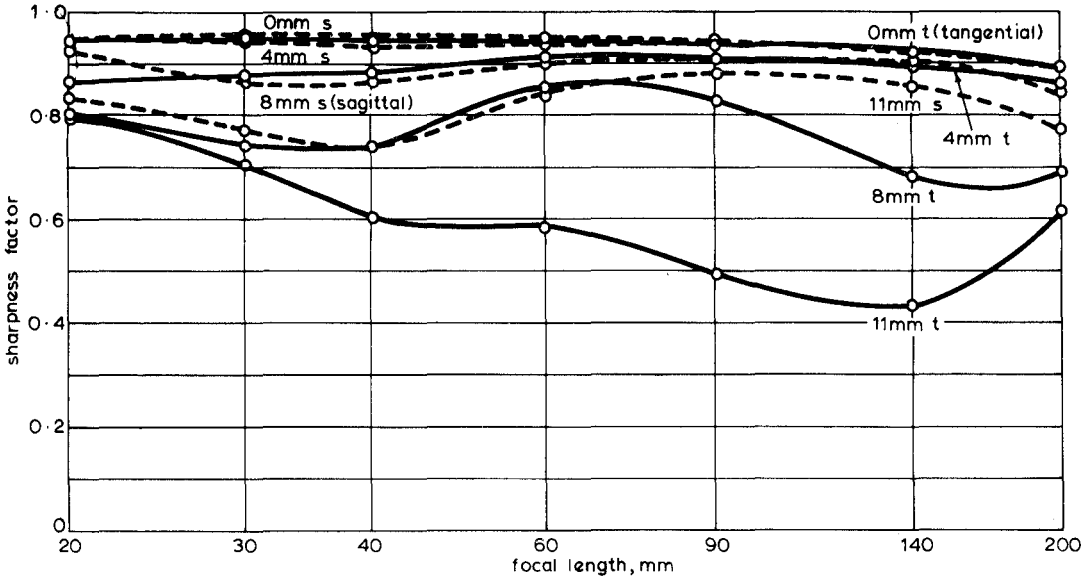

Fig. 27 - Sharpness factor at f/2·8

Lens No. 635930

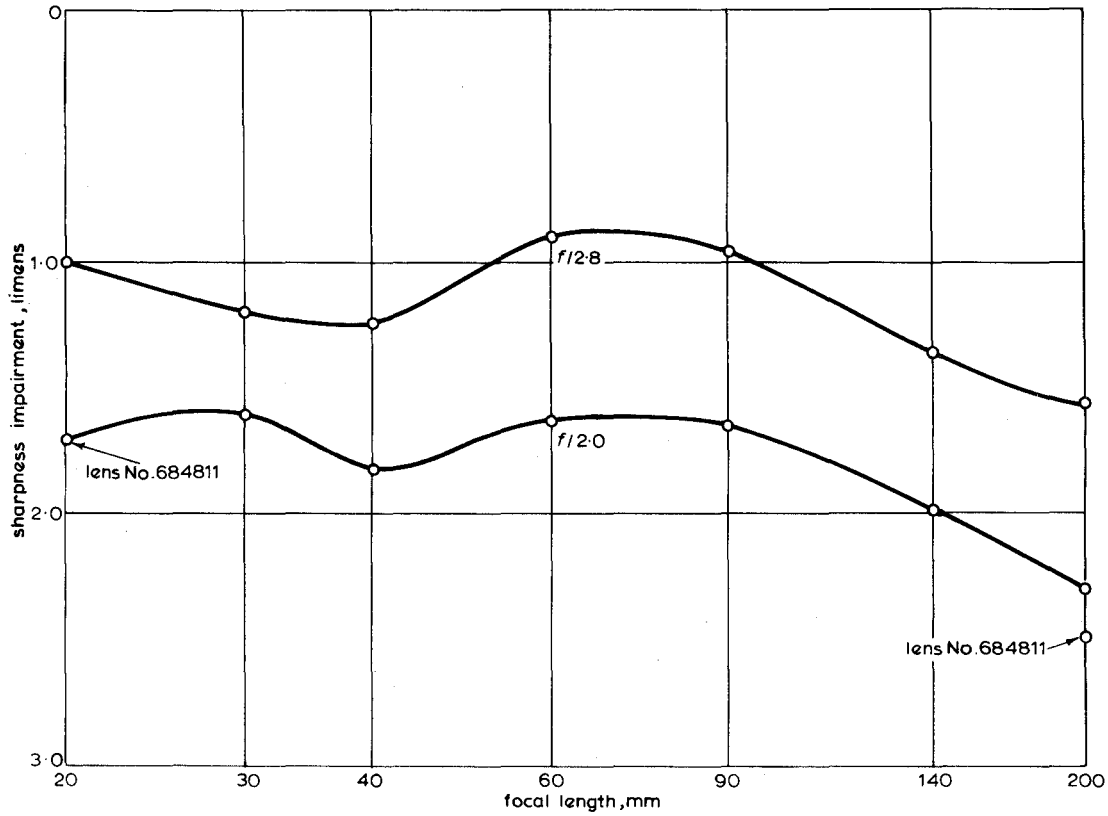

Fig. 28 - Image sharpness impairment for two apertures

Lens No. 635930

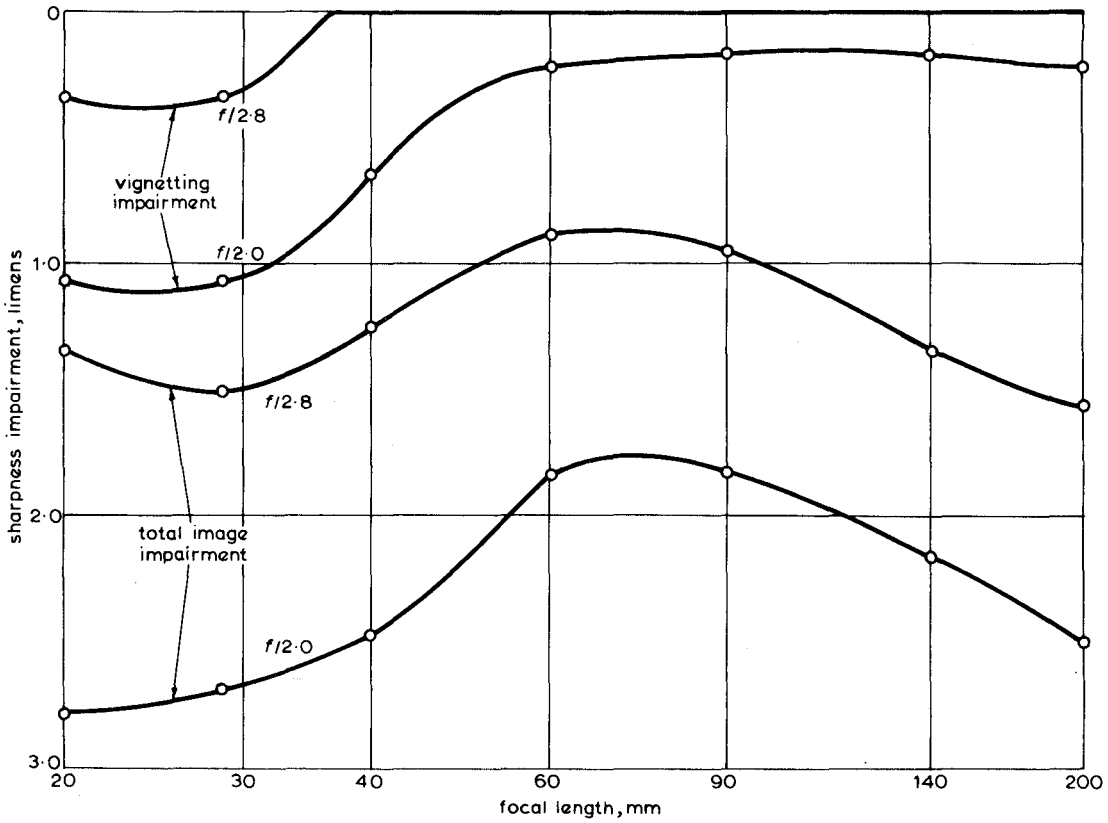

Fig. 29 - Image sharpness impairment for two apertures

Lens No. 635930

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